sPHENIX EMCAL Conceptual Design

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sPHENIX EMCAL Internal Review

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Requirements

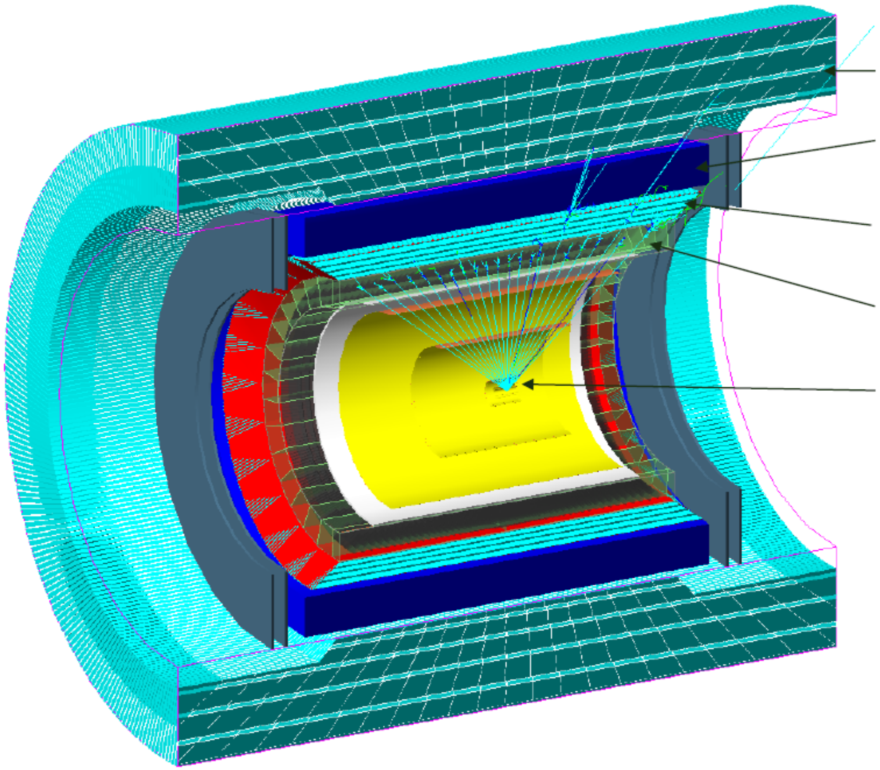
Physics Requirements

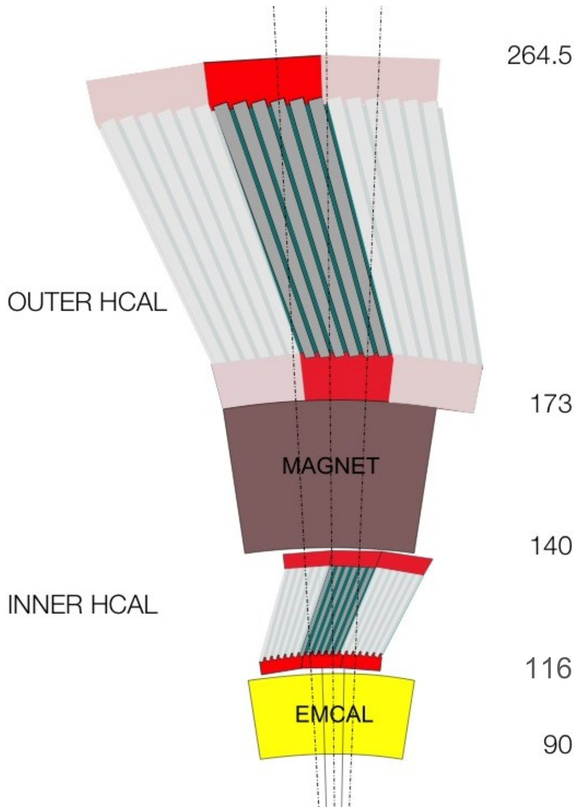
- Measure jets, γ-jets and direct single γ's up to p_T ~ 70 GeV/c
- Part of the combined EMCAL/HCAL calorimeter system
- Identify electrons and measure their energies for measuring Y's

Detector Requirements

- Large solid angle coverage ($\pm$ 1.1 in η, 2π in ϕ)
- Moderate energy resolution (~ 12%/$\sqrt{E}$)
- Must fit inside BaBar magnet
  - Occupy minimal radial space ($\Rightarrow$dense)
  - Compact ($\Rightarrow$ short X_0, small R_M)
  - High segmentation for heavy ion collisions
- Minimal cracks and dead regions
- Projective (approximately)
- Readout works in a magnetic field
- Low cost

The sPHENIX EMCAL





- EMCAL must be inside the magnet to minimize material in front
- Inner radius needs to be ~ 90 cm for occupancy considerations in heavy ion collisions and to allow for tracking and possible future particle ID
- Need to keep ΔR as small as possible to minimize size and cost of HCAL

$$\Rightarrow \Delta R = 116 - 90 \text{ cm } (26 \text{ cm})$$

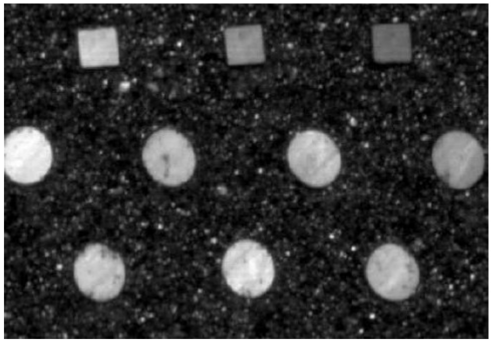
Technology Choices

Tungsten SciFi SPACAL

Absorber

- Matrix of tungsten powder and epoxy with embedded scintillating fibers
- Density ~ 10 g/cm^3
- X_0 ~ 7 mm (18 X_0 total), R_M ~ 2.3 cm

Material	Pb	W
ρ (g/cm^3)	11.3	19.3
X_0 (mm)	5.6	3.5
R_M (mm)	16.0	9.3

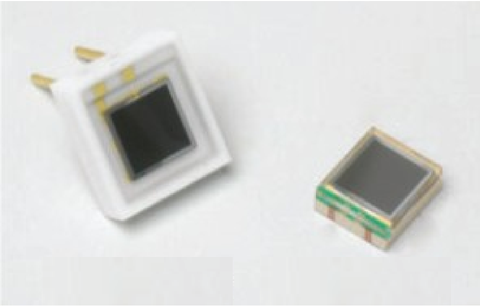


Scintillating fibers (Kuraray SCSF78)

- Diameter: 0.47 mm, Spacing: 1 mm
- Sampling Fraction ~ 2 %

Readout

- Silicon Photomultipliers (SiPMs/MPPCs)
- Gain ~ 2x10^5, PDE = 25%
- Dynamic range > 10^4 (15 μm pixel device $\rightarrow$ 40K pixels)
- Work inside magnetic field
- Large gain dependence on temperature
- Susceptible to radiation damage from neutrons

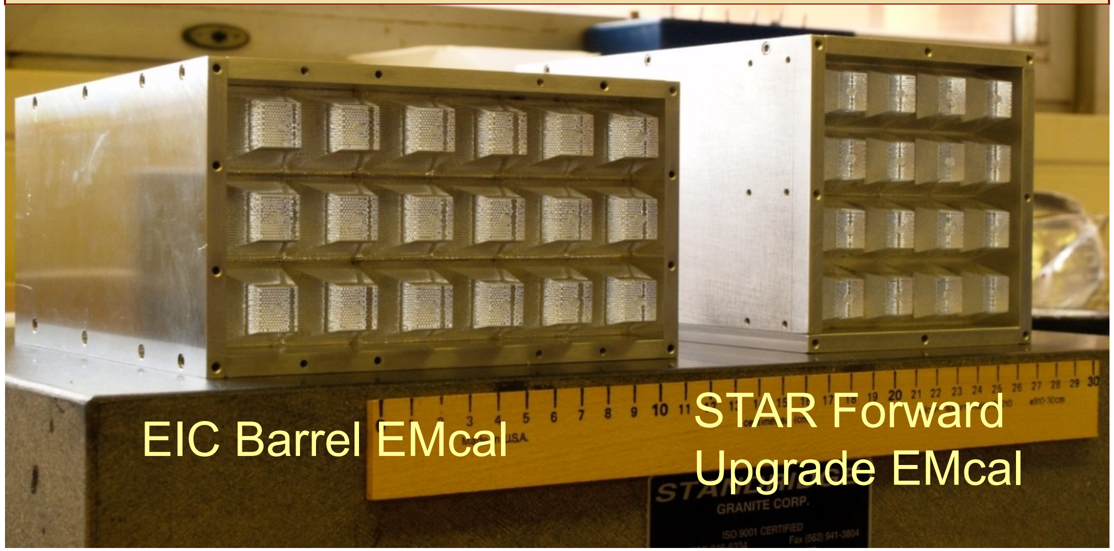


Hamamatsu S12572-015P
3x3 mm^3 MPPC

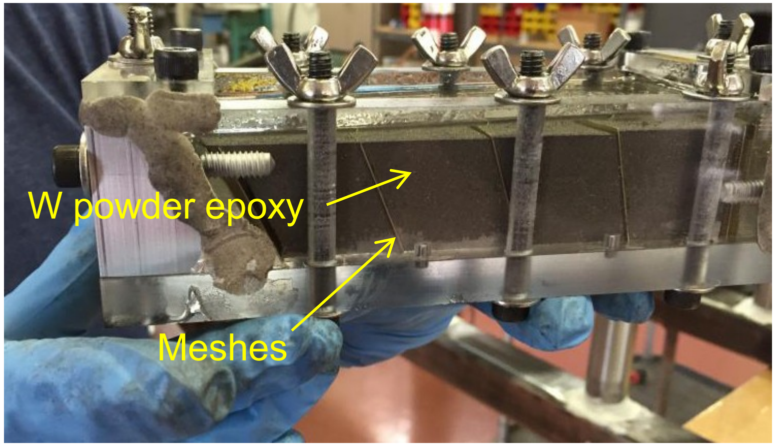
W-SciFi Spacal

Developed at UCLA by Oleg Tsai

Prototype Calorimeters



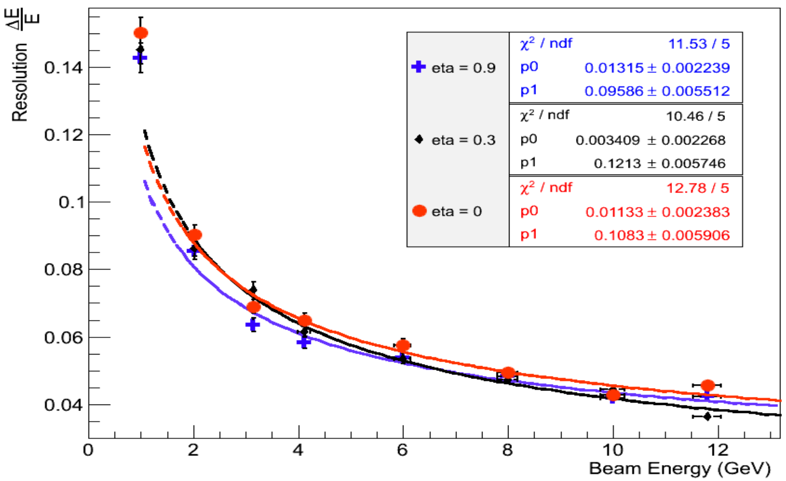
- Modules are formed by pouring tungsten powder and epoxy into a mold containing an array of scintillating fibers
- Fibers are held in position with metal meshes spaced along the module



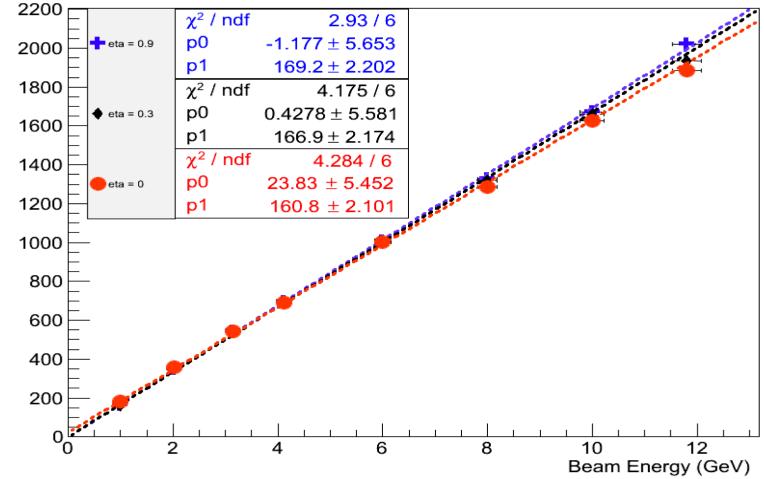
W/SciFi Performance

Beam tests at Fermilab in 2012, 2014 and 2015

Energy resolution at different rapidities



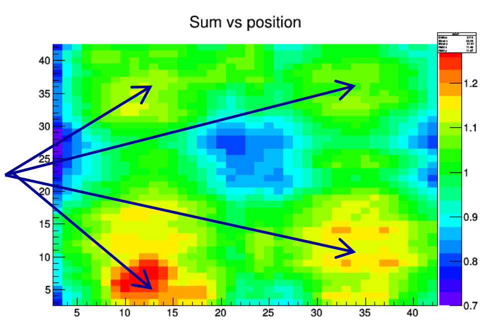
Linearity at different rapidities



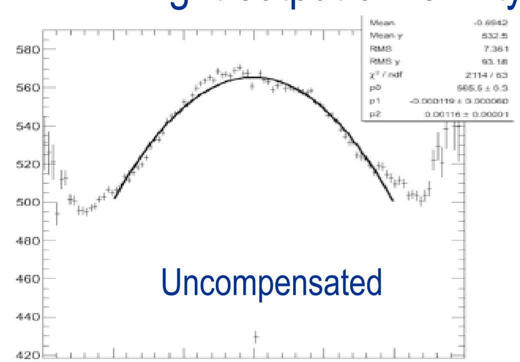
Energy resolution ~ 12%/√E

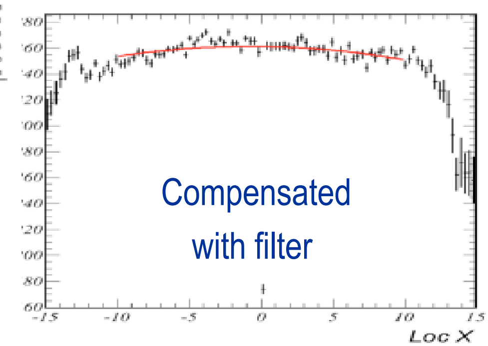
Light Yield ~ 500 p.e./GeV

4 SiPMs



Light output uniformity determined by readout

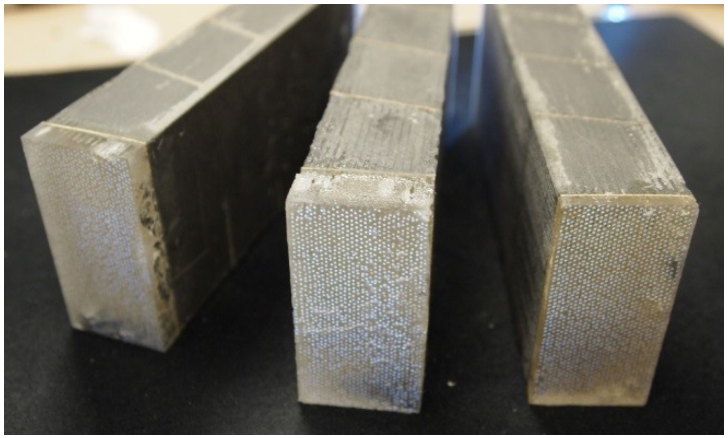




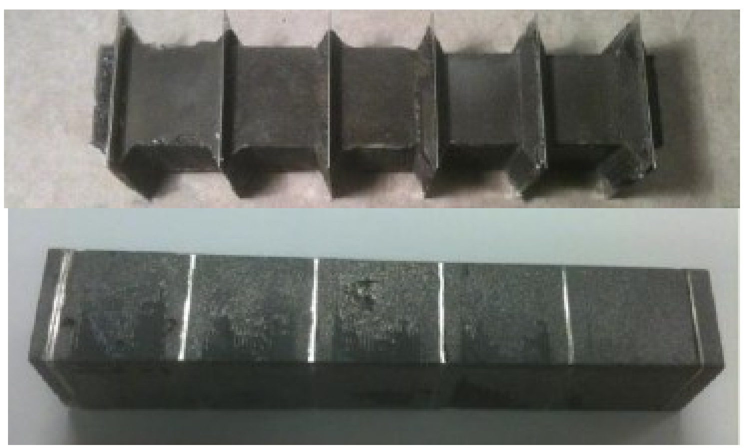
Producing W/SciFi Modules

BNL

1D Projective



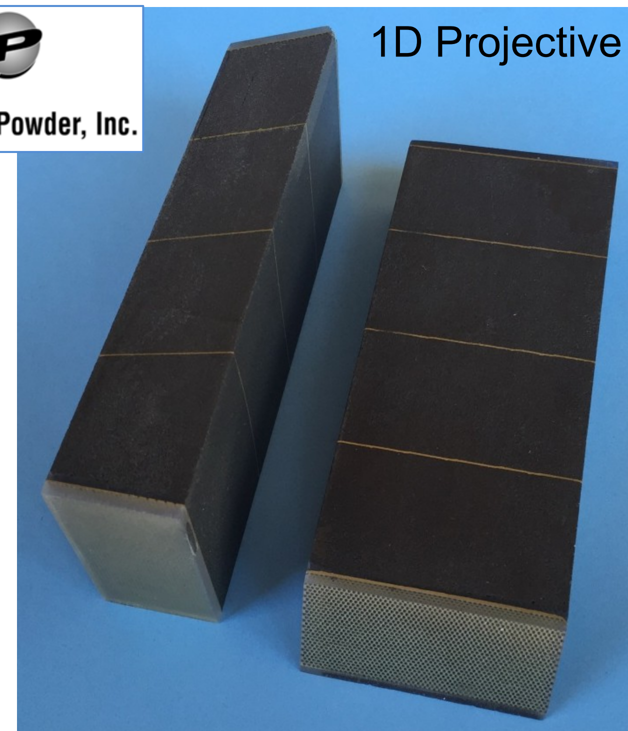
2D Projective



UIUC

1D Projective

THP
Tungsten HEAVY Powder, Inc.



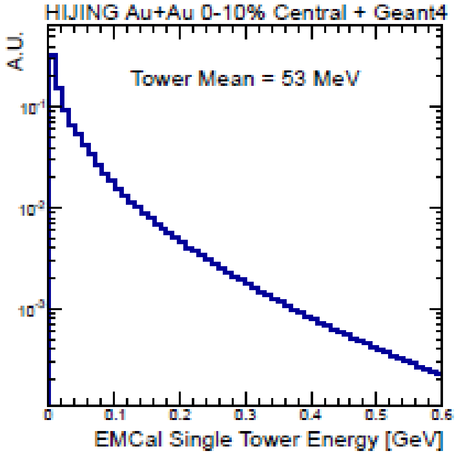
Segmentation

Segmentation, as well as requirement on energy resolution, is determined by energy from underlying event in central heavy ion collisions

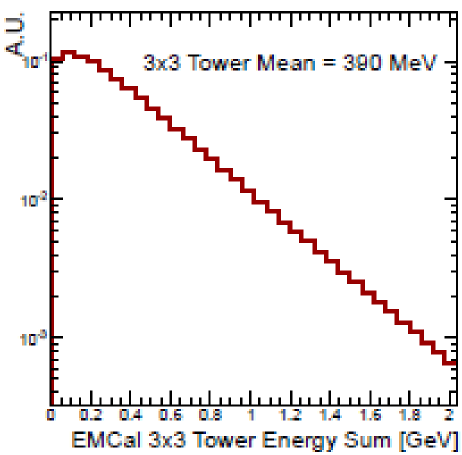
$\Delta\eta \times \Delta\varphi \approx 0.025 \times 0.025$

$\Rightarrow$ 96 x 256 = 24576 towers

Hijing Central Au+Au



Average energy per tower ~ 53 MeV



Energy in a 3x3 tower sum ~ 390 MeV

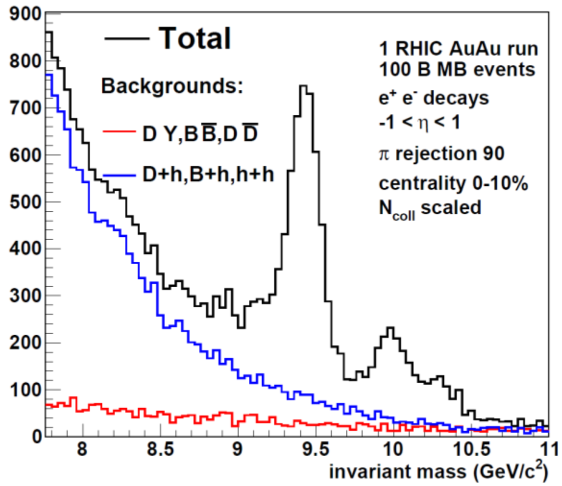
Direct γ-jet, p_T > 10 GeV

12%/$\sqrt{E}$ $\Rightarrow$ σ_E ~ 380 MeV

Projectivity

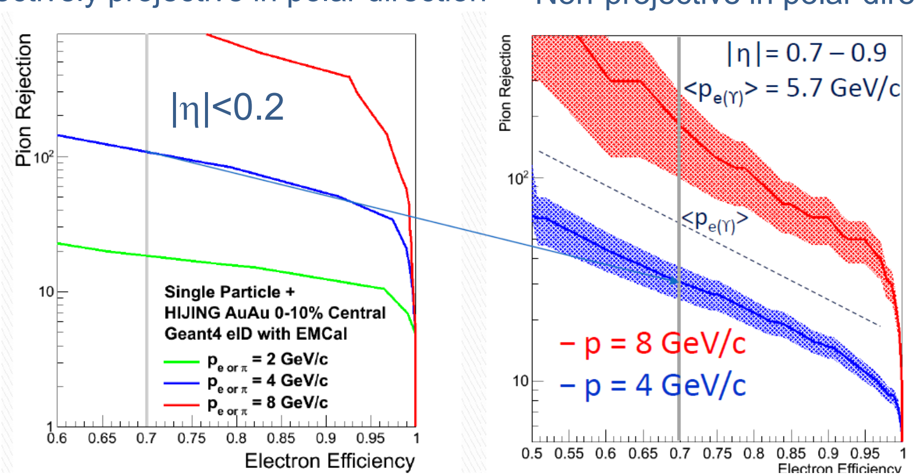
Due to the high multiplicity in central heavy ion collisions, having a fully (2D) projective (or at least *approximately* fully projective) calorimeter has many advantages

Require hadron rejection ~100:1 with electron efficiency ~ 0.7 to identify the Υ with high efficiency

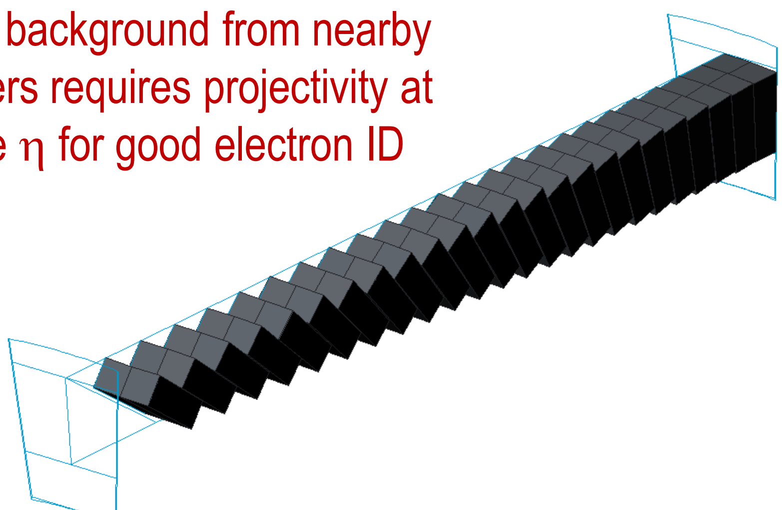


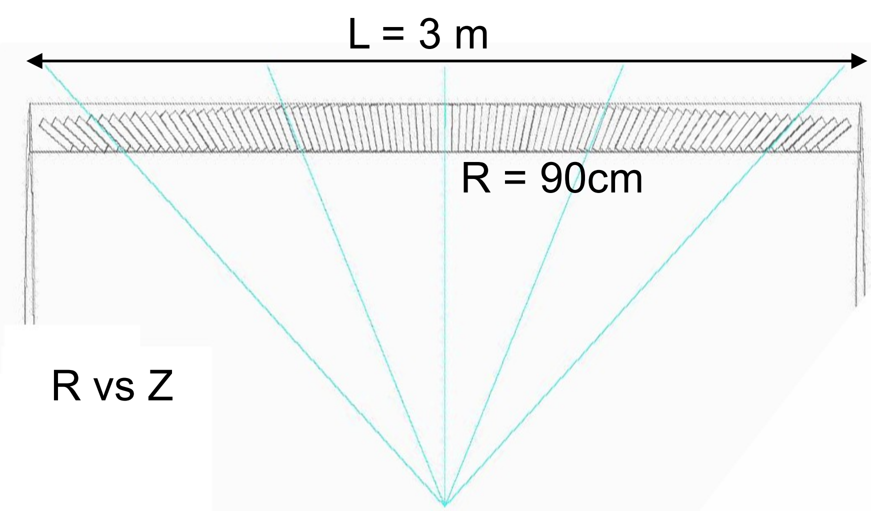
Effectively projective in polar direction

Non-projective in polar direction

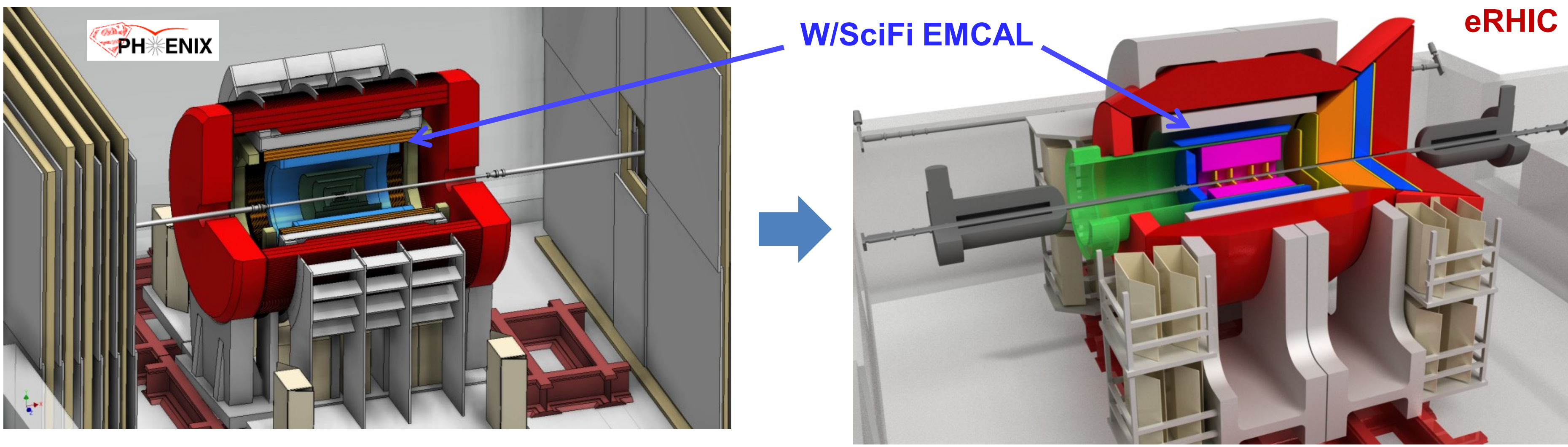


Large background from nearby showers requires projectivity at large η for good electron ID





sPHENIX → EIC Detector



The EMCAL will play a major role in EIC physics

The calorimeter requirements for sPHENIX and eRHIC are different in some ways (e.g., multiplicity and occupancy requirements) but similar in many other ways (e.g., solid angle coverage, energy resolution, etc.).

The sPHENIX EMCAL will satisfy the requirements of *both experiments.*

Summary

- sPHENIX requires an EMCAL with moderate energy resolution (~ 12%/$\sqrt{E}$) and large solid angle coverage to measure jets and Υ's to high p_T in heavy ion collisions
- The technology choice of a W/SciFi spacal calorimeter will meet the requirements of sPHENIX, both in terms of energy resolution and the spatial requirements for fitting inside the BaBar magnet
- A 2D projective calorimeter is highly desirable in order to maintain good e/π separation for the Υ out to large rapidities.
- The calorimeter we plan to build for sPHENIX will also serve the needs for a first detector at eRHIC